Engine Control Research under NASA Aviation Safety Program Overview

OA Guo

RHC

February 28, 2012

Enhanced Engine Control Session

Session 1: Enhanced Engine Control

10:00 Overview - OA Guo

10:10 C-MAPSS40k Overview and Update - James Liu

10:30 Fast Engine Response Research - Ryan May

10:50 Piloted Evaluation of Fast Engine Response Mode - Jonathan Litt

11:10 Engine Icing Effects Simulation and Detection - Ryan May

11:30 Integrated Flight Propulsion Control Applications - James Urnes, SR. (Boeing)

11:50 Discussion - All

Enhanced Engine Research Overview

- Vehicle Systems Safety Technologies (VSST) project under Aviation Safety
- Lost of Control (LOC) Theme Problem under VSST
- Enhanced Engine Research for LOC
- Research Tool Development
- List of Research Activities

VSST Goal

(Aligned With National Policy & Priorities)

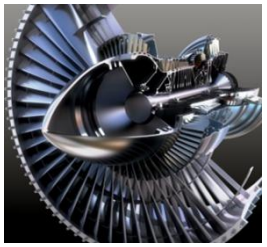
Develop technologies to reduce accidents and incidents through enhanced vehicle design, structure, systems, and operating concepts[1]

[1] U. S. National Aeronautics R&D Plan, Safety Goals 1 and 2, OSTP, 2010

Vehicle Systems Safety Technologies Overview

Improve Vehicle Safety by Proactively Mitigating Current and Future Risks

Improve Crew Decision-Making and Response in Complex Situations



Maintain Vehicle Safety between Major Inspections

Assure Safe and Effective Aircraft Control under Hazardous Conditions

Reduce current risks; Identify and proactively mitigate new risks

Assure Safe and Effective Aircraft Control under Hazardous Conditions (ASC)

Today

Aircraft Dynamics and Control Limitations under Hazardous Conditions can lead to Loss of Control (LOC)

- Current crew training under LOC conditions is limited due to model limitations for full stall conditions, failures and damage, and environmental hazards
- Information currently provided to the crew does not clearly inform of impending LOC
- Current autopilot systems are designed for nominal operations and often disengage under off-nominal conditions
- Current envelope protection systems provide limited capabilities

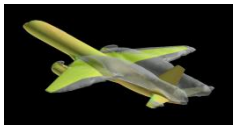
Tomorrow

Potential Increase in LOC Accidents Resulting from

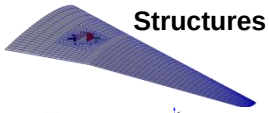
- Increasing demand on the National airspace requiring high-density operations
- Increased demand on crew & automated systems
- Increased external hazard encounters (wakes, weather)
- New materials and vehicle configurations

Enhanced Vehicle Simulation under Hazardous Conditions

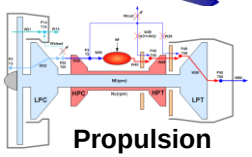
Aerodynamics



Structures

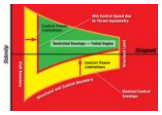


Propulsion

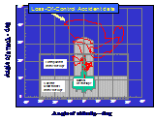


Safe & Effective Vehicle Control under Multiple LOC Hazards

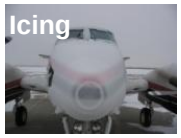
LOC Risk Prediction & Dynamic Envelope Estimation

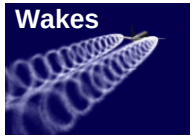


Upset Prevention & Recovery



Multiple Hazards Mitigation





LOC Working Group to Identify Emergent Risks, Define Test Scenarios, & Develop Evaluation Requirements

Enhanced Propulsion Research

- Past research and experience have shown that propulsion systems can be very effective in helping airplanes recover from adverse conditions:
  - TOC (Throttle-Only-Control) research experience
  - PCA (Propulsion Controlled Aircraft)

- However, preliminary studies show that there are many other potentially catastrophic scenarios in which airplanes could be saved if the engines could:
  - Better integrate with flight control system
  - Respond faster
  - Generate more thrust for a short period of time

Enhanced Engine Operation

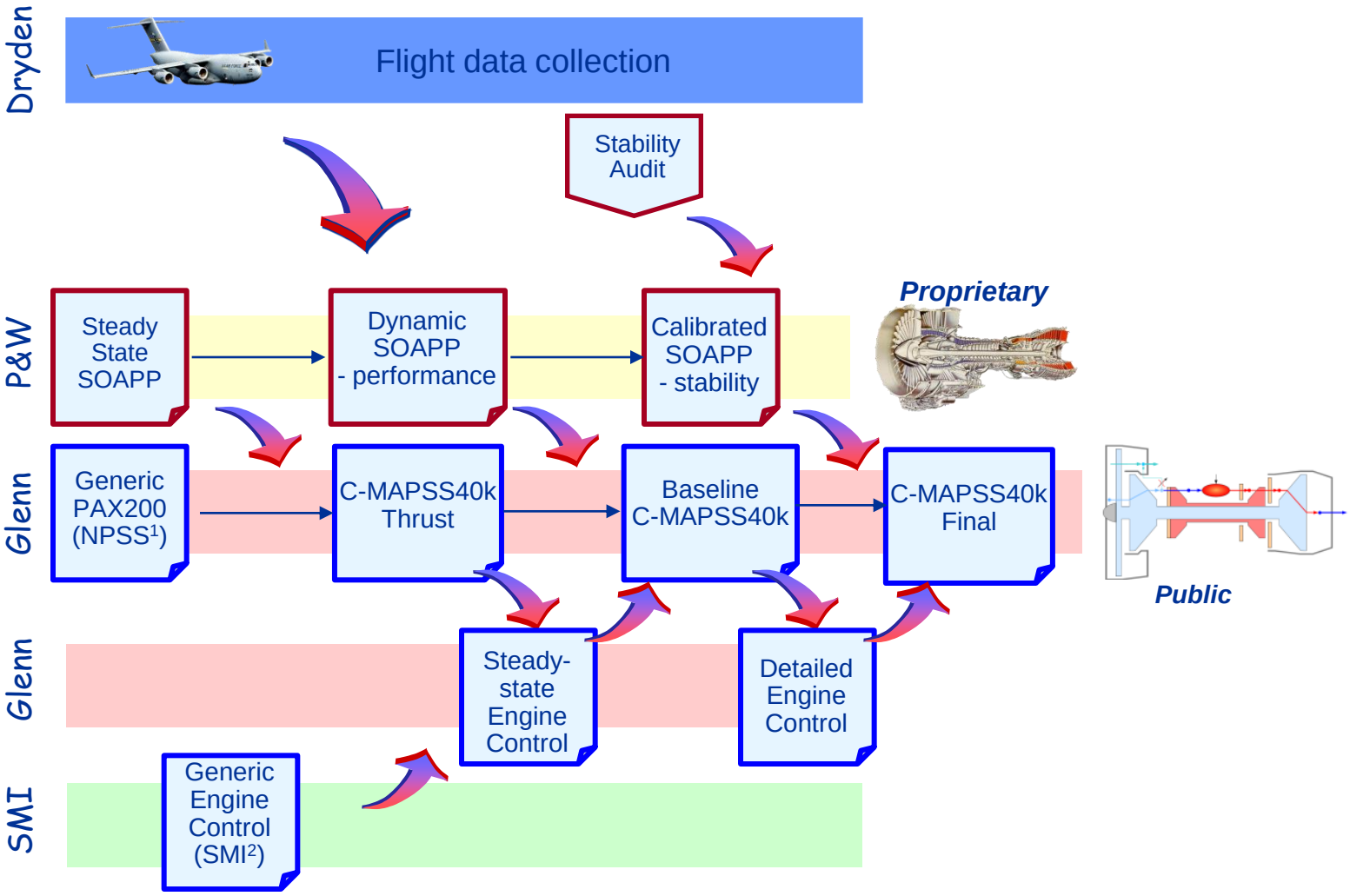
Engine dynamic simulation development

- And, we need an engine simulation that is capable of predicting the engine dynamics and controller reactions/limits

In 2006:

- No engine dynamic simulation available (government or industry)
- Information on stall margin over the flight and operation was not available
- No realistic engine controller that was comparable to the FADEC

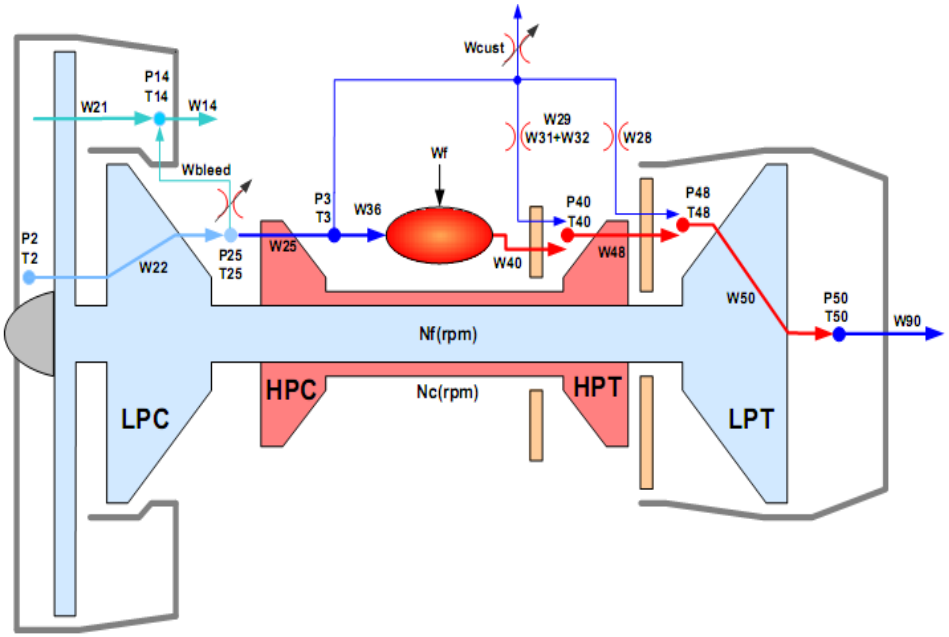
Creating A New High Fidelity Engine / Control Simulation



[1]Numerical Propulsion System Simulation, co-winner of the NASA Software of the Year Award for 2001
[2]Scientific Monitoring, Inc.

Commercial Modular Aero Propulsion System Simulation 40,000 (C-MAPSS40k)

- 40,000 Lb Thrust Class High Bypass Turbofan Engine Simulation
- MATLAB/Simulink Environment
- Publicly available
- Representative dynamic performance
- Realistic controller
- Realistic surge margin calculations



2011 GRC Software of the Year Award nomination, and Exceptional Achievement Award

Enhanced Engine Research Activities

- In-House Research:
  - Faster Response Engine Research
    - ✓ Control gain modification
    - ✓ Control limit modification
    - ✓ Risk management modeling
    - ✓ High speed idle
  - Off-Nominal Operation Modeling
    - ✓ Off-schedule VSV, VBV operation
    - ✓ High inlet angle operation simulation
    - ✓ Engine icing accretion simulation, detection, and control
- NRA:
  - "Fast Response Engine Research"- Scientific Monitoring, Inc. (Jan. 2007 – June 2010)
  - "Fast Response Engine Controller" – Pratt & Whitney (Jan. 2007 – June 2010)
- RTAPS:
  - "Piloted Flight Simulator Evaluation of Fast Engine Reponses" – Boeing, (August 2010 – June 2011)
  - "Integrated Flight and Propulsion Control Architecture Study" – Pratt & Whitney (Sept. 2011 – March 2013)
- SBIR:
  - "Robust Propulsion Control" - Scientific Monitoring, Inc. (Jan. 2011 – Aug. 2011)
  - "Incremental Sampling Algorithms for Robust Propulsion Control" - Aurora Flight Sciences Corporation (Jan. 2011 – Aug. 2011)

Thank you